THE VALUE OF THE EWIT COMPUTER PROGRAM IN IDENTIFYING ECONOMICALLY VIABLE RETROFIT OPTIONS FOR EXISTING COMMERCIAL BUILDINGS

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ABSTRACT

The Energy What If Tool (EWIT) program developed by the New Mexico firm of Area, Inc., offers architects and environmental designers a new and viable means to model the energy performance of their building designs while in the schematic phase by means of a personal computer. Previously the only way that such data could be obtained was by purchasing time on mainframe systems to run such programs as BLAST or DOE II. EWIT, however, is a program designed specifically to be run on the IBM personal computer; a machine well within the means financially of even the most modest office. The program yields data proven accurate to within 80-90% of the aforementioned BLAST and DOE II mainframe programs.

The purpose of this research effort is to investigate EWIT's potential as a tool for evaluating retrofit options for existing commercial buildings. To achieve this goal two case buildings in the Denver area were analyzed by means of the EWIT program. The first building is a one story structure of 10,000 square feet in floor area while the second is a hi-rise office building of almost a million square feet. The goal of the project is to produce a documented procedure for utilizing EWIT in retrofit applications and in the process develop VISICALC financial templates that can be integrated with the output from EWIT which would provide a comparative economic basis where the merits or shortcomings of various retrofit options can be quickly determined. While the above two case studies were conducted, space limitations would allow only the findings for the smaller structure (day care center) to be published in these proceedings. However, this case study does present a comprehensive picture of the EWIT retrofit analysis and its potential to architects and designers.

BASIC PRINCIPLES AND OPERATIONS OF THE EWIT PROGRAM

EWIT is a machine language program written for use exclusively on the IBM personal computer. It requires up to 120 pieces of input data regarding the building under study as well as environmental factors, occupant information, and mechanical systems. The user must supply certain climatic data to Area, Inc. who, for a moderate charge, will develop a weather file for the location of the building site. This weather file is then implemented easily into the main program where it is utilized during the calculation phase of the program's execution.

The program has three main operations: 1) building file creation, 2) calculation, and 3) data plot. When initially implementing EWIT in the investigation of a particular building, the above mentioned input data is entered into the computer where a "base-building" file is created. The computer then performs a simulation of the building's energy performance over a year's time. This simulation can be executed either on a seasonal or monthly basis depending on the user's preference and requires from 3-5 minutes of calculation time. The program achieves the task of modeling the performance of the building by calculating the energy loads for an "average" four days for each month or in the case of the seasonal option, four days from one month of each season. This calculation operation yields heating and cooling loads as well as BTU output produced by lights, appliances, occupants, solar gain, and conductance by the building's skin.

The final operation by EWIT involves the program's extensive graphics plotting capability. Any three of twenty-seven different variables can be plotted over a four season period showing peak BTU magnitude on a 24 hour basis. Thus the designer can study individual factors in a format that renders significant relationships more readily identifiable than in numeric form. For example, a plot of allowable heat gain, heat loss, and auxiliary loads would reveal the need for additional heating or cooling and show the impact of different themostat settings.

ADAPTATION OF EWIT FOR RETROFIT STUDY

As it was stated earlier, the primary thrust of this research effort is to explore EWIT's capability as a means of evaluating retrofit options for existing commercial buildings. The process for using the program in a retrofit mode involves steps that differ substantially from the conventional process followed for schematic design. When studying a building for possible retrofit modifications, a weather file based on a specific year must be compiled to be instituted into the main program. To create this file, the programmers at Area, Inc., require weather data consisting of the average minimum and maximum wet bulb and dry bulb temperatures for each month of the same year. This can be a formidable undertaking as many weather agencies are geared toward providing climatic data that is intended mainly for air and naval travel. Even institutions such as the Solar Energy Research Institute or the National Center for Climatic Research will be hard pressed to have data such as solar insolation statistics readily available. As a last resort the National Climatic Center in Asheville, N.C. will have all essential data on hand stored on computer tape.

The next step in a retrofitting evaluation using EWIT is to obtain as-built construction drawings of the building in question. Drawings showing floor plans, elevations, and wall/roof sections as they exist in reality are essential. One must also obtain a complete set of utility records of the building for the year under study. The building's management must be interviewed to determine day and night thermostat settings, and whether or not an economizer-cycle and/or a computer energy management system is used in the building. In addition, the plant management can give important facts on the HAVC system including system efficiency and coefficient of performance; factors critical to the success of the evaluation. The users of the building must also be interviewed to determine hours of building use as well as general occupant patterns. Such information might include after-hours use in regards to the number of personnel present in the structure at night or on weekends as well as any unusual seasonal use patterns.

Once the above information is obtained, the base building file can be compiled and the initial runs executed. At this point the investigation enters a phase where the user must possess a thorough understanding of the building components as well as a comprehensive knowledge of how each of the input variables affect the eventual output of the program. This aspect of the operation essentially involves comparing the heating and cooling loads of the building as projected by EWIT against the actual energy consumption during the year as documented by the year's utility records. Since the utility records are presented in a financial format, the EWIT load projections are most easily utilized if they too are presented in an economic basis. This transition from BTUs to dollars and cents is accomplished by means of a VISICALC spreadsheet template specially created for the purpose.

It is hoped that the EWIT projections will closely reflect the actual energy performance of the building under study and after discussion with consulting engineers and other practitioners of EWIT, a target accuracy of 80-85% was decided as being a realistic figure for which to strive, yet one that would provide a meaningful base from which to evaluate retro-fit options. It is rare that the initial EWIT runs will achieve this range of accuracy and therefore a process of fine tuning or "gaming" the program base file must be undertaken. This involves basically manipulating input data to more accurately model actual real-life conditions that govern the building. This ability to game the program requires a certain amount of ingenuity and resourcefulness which at times borders on an art. However, this skill in gaming the input is important to the success of using EWIT in retrofit evaluations as the program must model existing building performance with a reasonable amount of fidelity.

CASE STUDY: DAY CARE CENTER

The first of the two case studies is a day care center located in metropolitan Denver. The structure is one story in height with a floor area measuring 10,085 sq. ft. The building is rectangular in configuration with very few intricacies in terms of design. Because of its relatively small floor area and straightforward design, the day care center will serve as the main vehicle in demonstrating the process for utilizing EWIT in a retrofit project for energy conservation.

Building Description

Built in 1977, the Day Care Center is a relatively new structure composed of brick veneer on a metal stud framing system. The roof is a typical built-up bitumen system with over 4 inches of rigid insulation on metal decking. All windows are made of single-pane, solar bronze glazing encased in metal sash. Floors are covered with short weave carpet except in high traffic areas where vinyl tile is used. U-values of walls and the roof are .07 and .10 respectively. Heating requirements are supplied by a gas-fired, forced air system while cooling is supplied by one evaporative chiller unit with a freon back-up system. An economizer cycle is used with a 55-degree cut-off temperature. A Honeywell energy management system monitors and regulates the night time start-up and shut down of the heating/cooling systems. In essence, the computer monitors the outdoor temperature and compares this to interior mass temperatures where it then calculates the optimum start-up/shut-down time of the HVAC system.

Building Occupant Information

The center serves approximately 150 children daily during the workweek from September to May and in the summer months the figure drops down to about 100 children daily. The staff is composed of about 25 adults who oversee the facility from 7:30 a.m. to 6:00 p.m. daily except on weekends when the Center is closed. In addition, the Center is closed during the latter half of December through the month of January.

Creation of the EWIT Building File

At this point sufficient information has been acquired to actually begin the execution of the EWIT program. It is assumed that the appropriate climatic data has been sent to Area, Inc. and that this information has been converted into a weather file specific to the locality and time frame particular to the situation at hand. (Note--in the case of this research effort, 5 weeks were required to gain acquisition of the necessary data). The following is an entry-by-entry listing of the prompts given by the program followed by the input data as pertains to this case study building.

Entry #1 Building location (latitude, longitude) and altitude of the site.

Entry #2 Floor area, slab floor perimeter, and linear loss coefficient of the building.

Entry #3 Maximum outdoor air flow (ventilation and infiltration) in cfm.

Entry #4 The cutoff temperature of the economizer (if applicable)

Entry #5 Classify the internal mass according to the following:

1) carpet w/ acoustical ceiling
2) carpet w/ exposed mass walls or ceilings
3) vinyl tile floor
4) exposed mass floor and walls

Entry #6 Total number of surfaces (walls and roof, a maximum of 10 surfaces)

Entry #7 Absorptivity of the walls and the roof.

Entry #8 Area, U-value, and orientation (azimuth) for each surface (maximum of 10 entries).

Entry #9 For each surface of glazing listed above, give the glass height, internal shading coefficient, and the length of any overhang.

Entry #10 Maximum sensible occupant load, lighting load, and equipment load (BTU/hr).

Entry #11 The fraction of maximum for the above loads in each of the following time blocks: 1:00-8:00, 9:00-17:00, 18:00-24:00.

Entry #12 The fraction of maximum outdoor airflow in each of the above time blocks.

Entry #13 The minimum temperature for each of the time blocks.

Entry #14 The maximum temperature for each of the time blocks.

Entry #15 The overall efficiency of the heating system.

Entry #16 The overall cooling system COP.

Once the above information has been input into the program then the calculate phase of the program can be executed either on a month-to-month or seasonal basis. When the initial output is received from the computer then the main task of comparing the projected loads from EWIT against the actual utility records of the building can commence. The VISICALC conversion template performs the task of converting EWIT load output (BTU-Sq. Ft.) into dollars/sq. ft. which can then be readily compared against monthly utility costs.

ANALYZING EWIT OUTPUT AND MODIFICATION OF INPUT VARIABLES

Once the initial EWIT readout is achieved then one can begin the investigative process to locate any input variable that may be in error. The heating loads should be checked against gas meter readings while projected cooling loads should reflect the electrical (kwh) readings. In the case of the Day Care Center, the first EWIT run indicated a much higher heating load then was shown in the utility records. Partial cause for this difference was a failure to remember that EWIT's projected heating loads need to be modified by dividing through by the efficiency rating of the heating system. This is due to the fact that initially more energy is required in the system than is generated from it in terms of heat. Therefore to derive the actual heating load that was needed, the utility record should be reduced by 25%. This adjustment alone will usually make a significant change in the figure and bring the projected load more in range with the actual recorded energy used by the building.

Despite the above adjustment, the projected vs. the actual loads were still outside the acceptable 15-20% error range with EWIT's loads on the high side. Variables which could contribute to the error were occupant use, lighting levels (watts/sq. ft.), ventilation levels (cfm), thermostat settings, and U-values of walls and roof; all of which had to be carefully examined for possible errors. In this case it was determined that the amount of watts/sq. ft. had been miscalculated from the lighting plan and the plant engineer in charge of maintaining the center confirmed that the cfm figure for ventilation was too high as originally entered in the building file. The result of these changes was that higher lighting levels produced more heat and that lower cfm levels meant less cold exterior air to be heated. The net effect was a lower heating load projected by EWIT that fell to within 15% of that logged during the building for 1983.

Establishing the accuracy of EWIT's cooling load projections proved to be a much more difficult task as compared to that of establishing correct heating loads. This is due to the fact that there are appliance loads in addition to the chiller operation which act to hinder the overall electrical utility records from revealing the cooling load. It was determined that at best a correlation would have to be established between peak cooling loads shown by EWIT and the Kwh recorded in the utility records during warm months of the year.

In regards to EWIT accuracy, it is vital to remember that commercial buildings don't, in most cases, maintain a seven day work week. Therefore a special "weekend" run of the program must be performed that reflects the reduced number of occupants, lighting level, ventilation level, appliance loads, and other cutbacks in building use that occur on weekends. The loads that are produced by this special run must then be multiplied by 2/7 and then added or "spliced" together with 5/7's of the usual load figure to give a final "true" seven day week figure. In addition, peak demand will occur almost always during the work week and so a separate weekend calculation also helps to break out this important aspect. The weekday/weekend entry on the input sheet of EWIT allows this special operation.

Table 1 lists the VISICALC output data for a typical run for the day care center. The heating, cooling, lighting, and equipment loads are all translated into annual costs per square foot. The total cost estimate is $1.06/sq.ft./year, with lighting accounting for nearly 40% ($.422/sq.ft./year) of the total. Heating costs were slightly higher than cooling costs for this building located in Denver. The EWIT program can identify those end uses which are most significant, and retrofit options can then be tested to determine those most cost effective.

RETROFIT EVALUATION

The final step in the process involves the actual modeling of retrofit options in the study building by means of EWIT. There are different methods by which to "game" the effects of a retrofit device into the program depending on the building and nature of the option being considered. In most cases, however, the building envelope will not be altered but usually a simple add-on feature will be administered to the structure without a large capital outlay.

In beginning the evaluation phase the user will find the plots in EWIT to be an invaluable aid in determining which aspects of the structure would prove most effective in placement of retro-fit devices. In the case of the Day Care Center, the structure and use of the facility strongly suggested a skin-dominated situation. Therefore four plots were created that examined factors often found instrumental to skin-dominated situations: amount of heat gain/loss to air, total amount of heat loss allowable (determined by the "deadband"), the conduction load, the transmission loss of heat through glass and the auxiliary loading required by the building to remain in the comfort zone. Of particular note is the plot showing "allowable heat loss-allowable heat gain-auxiliary heat required." This plot establishes the "dead-band" mentioned above and shows immediately the need for additional heating or cooling within the structure (depicted by cross-hatched area). These resulting plots verified the intuitive judgement that conduction through walls, and, to a lesser extent, heat loss through glass were indeed responsible for a fair share of the heat loss.

To remedy a condition of this nature, it is not unusual to simply try and fix the windows with some type of insulating device. One such solution is an insulating shade known as the "Window Comforter"; an insulated fabric shade that mounts quickly into the existing window and delivers up to R-7 in insulation. This type of device is easily modeled on EWIT by simply changing the glazing type within the building file, in this case a type 10. The printouts and plots on the following pages show the results of the addition of the "Window Comforter" to the windows of the Center. EWIT projected a savings of approximately 8%/yr. or about $700 annually by using the "Window Comforter."

Table 2 lists the results of the cost estimates using the window comforter as a retrofit option. The annual energy cost per square foot has been reduced from $1.06 (Table 1) to $0.97. The installation of the window insulation had the greatest effect on the heating costs, reducing this item to approximately $0.22/sq.ft./year. The window comforter installation cost would be approximately $10,000, which would result in a simple payback of about 14 years. This particular retrofit is not very cost effective, but is shown as an example of the analysis capability of the EWIT program. Other retrofit options such as more efficient lighting or high efficiency air conditioners could be analyzed in a similar fashion.

CASE STUDY NO. 2: HI-RISE OFFICE BUILDING

As was stated initially in the paper, the limitation of space prohibits the detailed reporting of results for the second case study, the hi-rise office building. However, a brief discussion follows regarding the findings for that aspect of the research effort.

The second case study is a large hi-rise office building located within the central business core of Denver. The building contains approximately 900,000 sq. ft. of floor area and houses one of Denver's largest banks as well as providing 16 stories of office space in downtown Denver. The building is actually three inter-connecting "towers" that form a complex that covers a square city block. This non-uniform configuration and the vast amount of floor area in the building led to a different approach in analyzing the structure with EWIT. Because the building is composed of three smaller "sub-buildings," it was decided to treat each of the component structures as individual buildings and then add the results of the three runs to produce composite analysis of the overall building.

At this point it must be pointed out that the accuracy achieved in the first case study will not be realistic in a building of this magnitude. In a building containing almost a million square feet of floor area the interplay of thermal gain and loss is highly complex and even mainframe programs would require many runs and a great deal of time to produce a detailed simulation for such a large scale problem. While EWIT cannot be expected to do what a mainframe cannot, it can give investigators and analysts valuable data concerning building performance for retrofit options. There are several data input problems that are unique to large buildings which were not encountered in the first case study. For example, the hi-rise case study involved several groups of users who utilized the building during different time schedules and required different energy demands. The HVAC system of this building differed greatly from the day care center as it involved a multiple unit chiller that operated at variable capacity during the different seasons of the year. These are only a couple of the special problems that require yet more "gaming" techniques that will, once again, adjust the input to give an accurate picture of the actual building performance.

While EWIT was not able to achieve the simulation accuracy as in the case of the day care center, it did prove to be an outstanding aid in determining the implications of major influences to the building. For example, buildings located within downtown cores of large cities are influenced by the shadows from neighboring tall structures. EWIT can simulate this "shadow condition" by changing the internal shading coefficient (entry #9) for a particular elevation to simulate the lack of radiation that enters the interior of the building under study.

REFERENCES

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QLOADS	WEEKDAY	WEEKEND	*UTILITY RATES*		*MECHANICAL DATA*		*PEAK DATA*	
EQUIPT.	1112	0	CONSUMPT.	.0206	C.O.P.	2	EQUIP.	.339
COOLING	5220	1930	DEMAND	9.52	EFFIC.	.75	COOL.	16.287
LIGHTING	30380	3739	GAS	.35065	GAS EFF.		LIGHT.	8.5
HEATING	65018	47965					HEAT.	

(DAY CARE CENTER, RUN #3)

ANNUAL UTILITY COSTS ESTIMATE

END USE	-CONSUMPTION- ELECT	ELECT	GAS	GAS	TOTAL	TOTAL	DEMAND ELECT.	ELECT.	TOTAL
---------	KBTU/S.F.	$/S.F	KBTU/S.F.	$/S.F.	KBTU/S.F	$/S.F.	KW/S.F.	$/S.F.	$/S.F.
EQUIPT.	.7942857	.0047941			.7942857	.0047941	.0011919	.0113470	.0161411
HOT WATER			0	0	0	0	-	-	0
COOLING	2.144136	.0129415			2.144136	.0129415	.0286323	.2725794	.2855208
LIGHTING	22.78431	.1375203			22.78431	.1375203	.0298857	.2845122	.4220325
HEATING			80.46837	.3359075	80.46837	.3359075			.3359075
TOTAL	25.72273	0.16	80.46837	0.34	106.1911	0.49	.0597099	0.57	$1.06

Table 1. Day Care Center Cost Estimate-EWIT Program

QLOADS	WEEKDAY	WEEKEND	*UTILITY RATES*		*MECHANICAL DATA*		*PEAK DATA*	
EQUIPT.	1112	0	CONSUMPT.	.0206	C.O.P.	2	EQUIP.	.339
COOLING	6513	4486	DEMAND	9.52	EFFIC.	.75	COOL.	17.508
LIGHTING	30380	3739	GAS	.35065	GAS EFF.		LIGHT.	8.537
HEATING	44848	23950					HEAT.	25

(RETRO-FIT OPTION #1)

ANNUAL UTILITY COSTS ESTIMATE

END USE	-CONSUMPTION- ELECT	ELECT	GAS	GAS	TOTAL	TOTAL	DEMAND ELECT.	ELECT.	TOTAL
---------	KBTU/S.F.	$/S.F	KBTU/S.F.	$/S.F.	KBTU/S.F	$/S.F.	KW/S.F.	$/S.F.	$/S.F.
EQUIPT.	.7942857	.0047941			.7942857	.0047941	.0011919	.0113470	.0161411
HOT WATER			0	0	0	0	-	-	0
COOLING	2.976541	.0179656			2.976541	.0179656	.0307788	.2930141	.3109797
LIGHTING	22.78431	.1375203			22.78431	.1375203	.0300158	.2857506	.4232709
HEATING			51.97305	.2169565	51.97305	.2169565			.2169565
TOTAL	26.55514	0.16	51.97305	0.22	78.52818	0.38	.0619865	0.59	$0.97

Table 2. Day Care Center Cost Estimates Using the Window Comforter Retrofit Option.